

# CVD SINGLE CRYSTAL DIAMOND FOR EXTREME UV PHOTODETECTION

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## Abstract

The fabrication and the characterization of a high quality CVD single crystal diamond UV/VUV photodetector is reported. Such a device was tested over a very wide spectral range, from the extreme UV (20 nm) up to the near IR region (2400 nm).

Different experimental setup were adopted. An Optical Parametric Oscillator (OPO) tunable laser was used to investigate the 210-2400 nm region in pulse mode. In this region the spectral response shows an UV to visible contrast of about 6 order of magnitude. A fast time response of at least 5 ns, i.e. the laser pulse duration, was observed.

A vacuum monochromator with a deuterium lamp was used to measure the device responsivity in the 120-250 nm spectral range in a continuous mode. DC gas discharge sources in the extreme UV region and a toroidal grating vacuum monochromator were used to measure the device response down to 20 nm. In both cases, device time response lower than 0.2 s was measured, which is the minimum acquisition time allowed by the used electronics.

In all measurements neither persistent photoconductivity nor undesirable pumping effects were observed so that extremely good stability and reproducibility of the device response were obtained.

## INTRODUCTION

Due to its outstanding physical properties, diamond is an ideal candidate for a number of technological and commercial applications, in which extreme operating conditions are required. Indeed, diamond based devices have been shown to withstand harsh environments, high temperatures, high ionizing particle fluxes as well as intense X-Rays and Vacuum Ultraviolet (VUV) irradiation [1,2]. In particular a radiation hard and visible blind detector with a good responsivity in the VUV region is a relevant issue in both astrophysics and nuclear fusion experiments. At present, such practical applications are prevented either by the relative poor quality of polycrystalline diamond films or the very high cost and rareness of detector grade natural diamonds. This is why a great effort is now being devoted from a number of research groups in order to produce high quality single crystal CVD diamond films.

## EXPERIMENTAL AND RESULT

A 150  $\mu\text{m}$  thick single crystal diamond film was deposited by Microwave CVD on a  $5\times 4\times 0.3\text{ mm}^3$  (100) oriented (HPHT) diamond substrate. A UV photodetector was then realized by depositing interdigitated Al contacts on the CVD diamond surface by a standard photolithographic process.

The obtained device was then tested in the 210-2400 nm spectral range using an Optical Parametric Oscillator (OPO) tunable laser as light source (Opolette by Opotek), producing 5 ns pulses. In the 120-250 nm spectral range the device responsivity was measured in continuous mode (DC) by using a deuterium lamp and a 0.5 m vacuum monochromator (McPherson 280). In the extreme UV region a He DC gas discharge source and a toroidal grating vacuum monochromator (Jobin Yvon LHT-30) with 5 Å wavelength resolution were used.

In Fig. 1 the normalized responsivity is reported as a function of the incident laser radiation wavelength in the case of 100 V applied bias voltage. The detector shows more than five order of magnitude visible/UV rejection ratio and a very sharp drop of about  $10^4$  is observed in correspondence of the 225 nm diamond energy gap. At wavelengths

greater than 1300 nm the responsivity becomes lower than our detectable limit. It should be pointed out that the detector response is stable and highly reproducible, so that undesirable effect such as pumping or memory effects under irradiation could be excluded.

The vacuum UV and extreme UV spectral ranges were then extensively investigated using the above described experimental setup. As an example, the emission spectrum of a DC discharge He lamp is reported in Fig. 2, as measured by our single crystal diamond photodetector in the 20-65 nm interval. The He<sup>+</sup> 25.6 nm and 30.4 nm as well as the He<sup>++</sup> 58.4 nm emission lines are clearly detected, assessing a very good detection capability of the device even in this extreme UV spectral region.

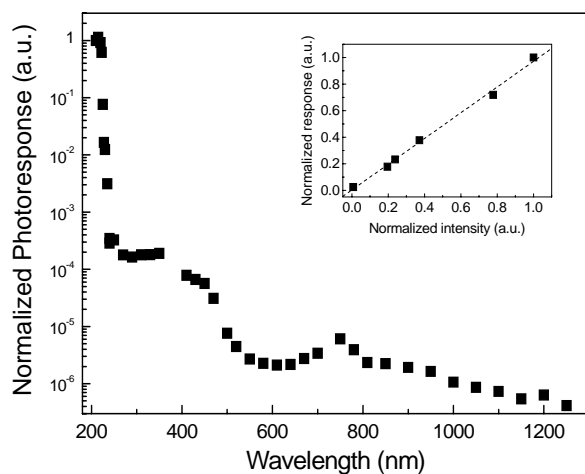
In the inset of Fig. 2 the response to t=20 s irradiation intervals, at the wavelength of the 58.4 nm He<sup>++</sup> emission line, are reported using four different detector bias voltages. It's worth noting that a very good signal to noise ratio is obtained even at bias voltages as low as 1 V. The rise time, which was estimated to be about 4 s, and the decay time, about 5 s, are completely ascribed to the electrometer preamplifier time constants. By properly choosing the instrument current scale, an upper limit of about 0.2 s can be derived for the diamond device time response, even though the real value is expected to be considerably lower.

## CONCLUSIONS

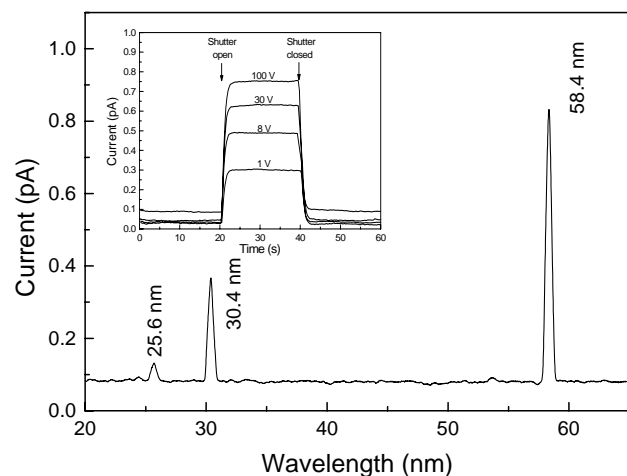
A CVD single crystal diamond UV/VUV photodetector was fabricated and tested over a very wide spectral range, from the extreme UV (20 nm) up to the near IR region (2400 nm).

In pulsed mode, a fast time response of at least 5 ns, i.e. the laser pulse duration, was observed. A time response lower then 0.2 s was measured in continuous mode, which is the minimum acquisition time allowed by the used electronics. In particular, a He lamp spectrum in the 20-65 nm range was clearly detected with a very good signal to noise ratio.

In all measurements no persistent photoconductivity nor undesirable pumping or memory effects were observed, so that extremely good stability and reproducibility of the device response were obtained.



**Figure 1** Normalized responsivity in pulsed mode as a function of the incident wavelength (full plot). Responsivity of the detector as a function intensity at 220 nm (inset).



**Figure 2** He spectrum in the 20-65 nm range as measured by the CVD single crystal detector (full plot). Photocurrent at 58.4nm for different bias voltages (inset). The rise and decay time are completely ascribed to the electrometer time constants.

## REFERENCES

1. McKeag, R. D et al. "Photoconductive properties of thin film diamond" *Diam. Relat. Mater.*, Vol. 6, 374-380 (1997)
2. Brescia, R. et al. "Photoconductive properties of single-crystal CVD diamond" *Phys. Stat. Sol.* , Vol. 199, 113-118 (2003).